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No. 95.

THE AVERAGE FORM

OF

ISOLATED SUBMARINE PEAKS,

AND

THE INTERVAL WHICH SHOULD OBTAIN BETWEEN DEEP-SEA SOUNDINGS TAKEN TO DISCLOSE THE CHARACTER OF THE BOTTOM OF THE OCEAN.

BY

G. W. LITTLEHALES,
U. S. HYDROGRAPHIC OFFICE.

Under the direction of
LIEUTENANT RICHARDSON CLOVER, U. S. N.,
Acting Hydrographer.

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AN INQUIRY INTO THE AVERAGE FORM OF ISOLATED SUBMARINE PEAKS, AND THE INTERVAL WHICH SHOULD OBTAIN BETWEEN SOUNDINGS TAKEN TO DISCLOSE THE CHARACTER OF THE BOTTOM OF THE OCEAN.

In a central region in the Atlantic Ocean, though somewhat nearer the African than the American coast, in the neighborhood of the remarkable volcanic islands known as Madeira and the Canaries, recent bathymetric surveys have developed three unsuspected peaks rising abruptly out of the ocean, which here sinks to a depth of more than 2,000 fathoms. These, named Dacia Bank, Seine Bank, and the Salvages, together with Enderbury Island in the central part of the South Pacific Ocean, and the unnamed shoal within late years developed by the United States ships *Tuscarora* and *Ranger*, lying to the westward of San Francisco in the track of commerce, are taken as the basis of discussion, as they have been more fully explored than other formations of this class. The deep-sea soundings which have been observed in each of these localities are shown on the accompanying charts. Among eminent authorities there is great diversity of opinion concerning the proper interval between deep-sea soundings taken to develop the character of the bottom of the ocean and in searching for reported shoals. With regard to the relative slopes of land and submarine peaks the same diversity of opinion exists; some well-informed men asserting that land peaks, although perhaps originally of the same general slopes as those beneath the surface of the ocean, have been diminished in steepness by the gradual weathering and transference of the higher portions toward the base, while others maintain that as peaks formed in the ocean have the weight of the water to bear in addition to their own weight, their slopes must be less steep than those formed on land.

This inquiry is undertaken with a view of fixing the ideas of navigators as to the proper interval between deep-sea soundings taken to develop the existence of important changes in the bed of the ocean, and also with a view of affording some means of making comparisons between the slopes of land and submarine peaks by deducing the equation to the curve which, by revolution around a vertical axis, would generate the average of the surfaces of the submarine peaks above mentioned.

Theoretically the shape of an isolated submarine formation would be that of a solid of revolution in which the crushing strength of any section is equal to the combined weight of the portion of the formation above that section and of the superincumbent body of water.

Let y denote the radius of any section, and x its distance from the top of the formation.

Let K denote the co-efficient of crushing strength of the material of the formation, δ the weight of a unit of its volume, and δ' the weight of a unit of volume of sea-water.

Assuming that the top of the formation just reaches to the surface of the ocean,

$\pi\delta\int y^2dx =$ the weight of the formation above any section whose distance from the top is x,

$2\pi\delta'\int y.x.dy =$ the pressure of the water upon the formation above any section whose distance from the top is x,

$\pi Ky^2 =$ the strength of any section to resist crushing.

Then

$$\pi\delta\int y^2dx + 2\pi\delta'\int y.x.dy = \pi Ky^2 + C \quad . \quad . \quad . \quad . \quad (1)$$

in which C is a constant representing the excess of crushing strength in any section above what is necessary to withstand the pressure caused by the weight of the formation and the weight of the superincumbent body of water.

By differentiation, equation (1) becomes

$$\pi\delta y^2dx + 2\pi\delta' y.x.dy = 2\pi\, Ky.dy$$

or

$$\frac{\delta}{2}\frac{dx}{(K - \delta' x)} = \frac{dy}{y}$$

$$\frac{\delta}{2\delta'}\frac{dx}{\left(\frac{K}{\delta'} - x\right)} = \frac{dy}{y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

By integration, equation (2) becomes

$$\frac{\delta}{2\delta'}\log\left(x - \frac{K}{\delta'}\right) = \log y$$

$$\log\left(x - \frac{K}{\delta'}\right) = \frac{2\delta'}{\delta}\log y$$

$$x - \frac{K}{\delta'} = \varepsilon^{\frac{2\delta'}{\delta}\log y}$$

$$x = \frac{K}{\delta'} + \varepsilon^{\frac{2\delta'}{\delta}\log y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

As there are no well-determined data for the density and crushing strength of the materials which compose these formations, it seems most practical to form conditional equations by inserting observed values of x and y in equation (3) written in the form

$$x = A + B\varepsilon^{\log y},$$

and to find the values of the constants A and B by the Method of Least Squares. The following observed values, in which y is expressed in nautical miles and x in fathoms, are taken from the accompanying charts:

DACIA BANK.

$$\varphi = +31^\circ\ 10' \qquad \lambda = +13^\circ\ 40'$$

$$y = 1,\ 2,\ 2\tfrac{1}{2},\ 3,\ 4,\ 5,\ 7\tfrac{1}{2},\ 23\tfrac{1}{2},\ 26.$$
$$x = 335,\ 619,\ 757,\ 844,\ 1102,\ 1189,\ 1386,\ 1592,\ 1961.$$

SEINE BANK.

$$\varphi = +33^\circ\ 50' \qquad \lambda = +14^\circ\ 20'$$

$$y = 1,\ 2,\ 3,\ 6,\ 9,\ 13,\ 14,\ 14.$$
$$x = 289,\ 845,\ 1149,\ 1769,\ 2210,\ 2250,\ 2190,\ 2325.$$

THE SALVAGES.

$$\varphi = +30^\circ\ 05' \qquad \lambda = +15^\circ\ 55'$$

$$y = 1,\ 7\tfrac{1}{2},\ 12.$$
$$x = 778,\ 1688,\ 1827.$$

ENDERBURY ISLAND.

$$\varphi = -3^\circ\ 10' \qquad \lambda = +171^\circ\ 10'$$

$$y = 1\tfrac{1}{2},\ 3\tfrac{1}{2},\ 11\tfrac{1}{2},\ 17.$$
$$x = 880,\ 1991,\ 2370,\ 2835.$$

SHOAL IN NORTH PACIFIC OCEAN.

$$\varphi = +32^\circ\ 55' \qquad \lambda = +132^\circ\ 30'$$

$$y = 1,\ 3,\ 6,\ 12.$$
$$x = 388,\ 1045,\ 1870,\ 2282.$$

By inserting these values we have the following conditional equations:

(1)	335.000 = A + 2.718281828	0.000	B = A + 1.0000000
(2)	619.	0.301	1.3512
(3)	757.	0.398	1.4888
(4)	844.	0.477	1.6112
(5)	1102.	0.602	1.8258
(6)	1189.	0.699	2.0117
(7)	1386.	0.875	2.3988
(8)	1592.	1.371	3.9393
(9)	1961.	1.415	4.1165
(10)	778.	0.000	1 0000
(11)	1688.	0.875	2.3988
(12)	1827.	1.079	2.9418
(13)	289.	0.000	1.0000
(14)	845.	0.301	1.3512
(15)	1149.	0.477	1.6112
(16)	1769.	0.778	2.1771
(17)	2190.	1.146	3.1456
(18)	2210.	0.954	2.5961
(19)	2325.	1.146	3.1456
(20)	2250.	1.114	3.0465
(21)	388.	0.000	1.0000
(22)	1045.	0.477	1.6112
(23)	2282.	1.079	2.9418
(24)	1870.	0.778	2.1771
(25)	880.	0.176	1.1924
(26)	1991.	0.544	1.7229
(27)	2370.	1.061	2.2893
(28)	2835.	1.230	3.4213
	40766.000		= 28 A + 60.5132 B

From the above conditional equations the following normal equations are formed:

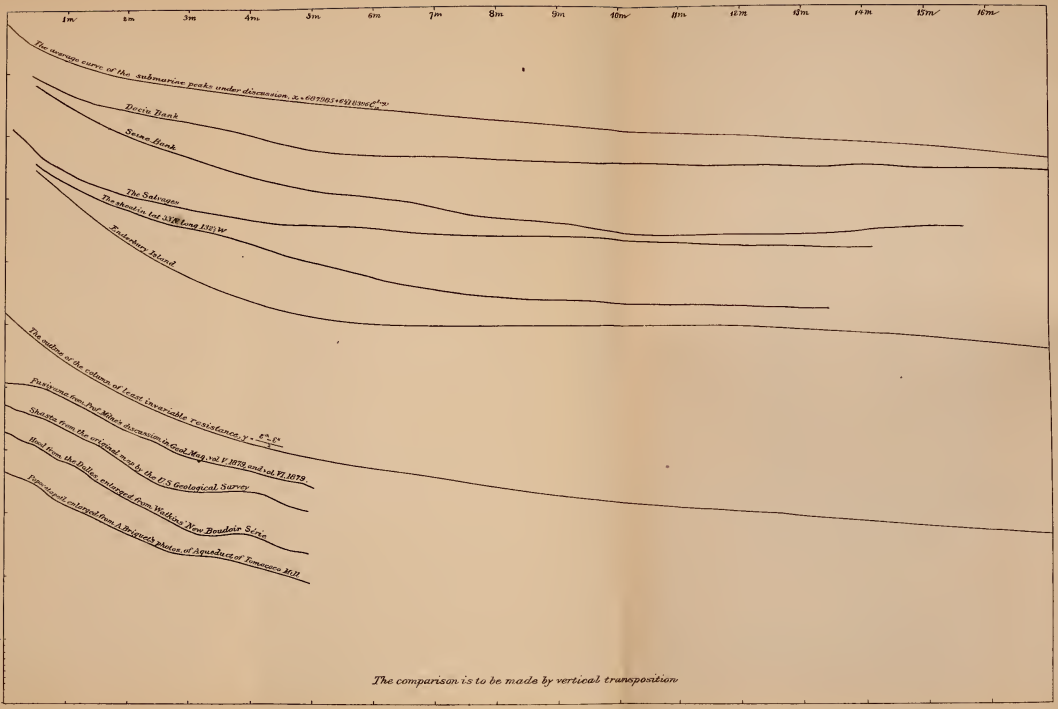
$$40766.000 = 28.000\ A + 60.513\ B$$
$$102321.027 = 60.513 + 152.932$$

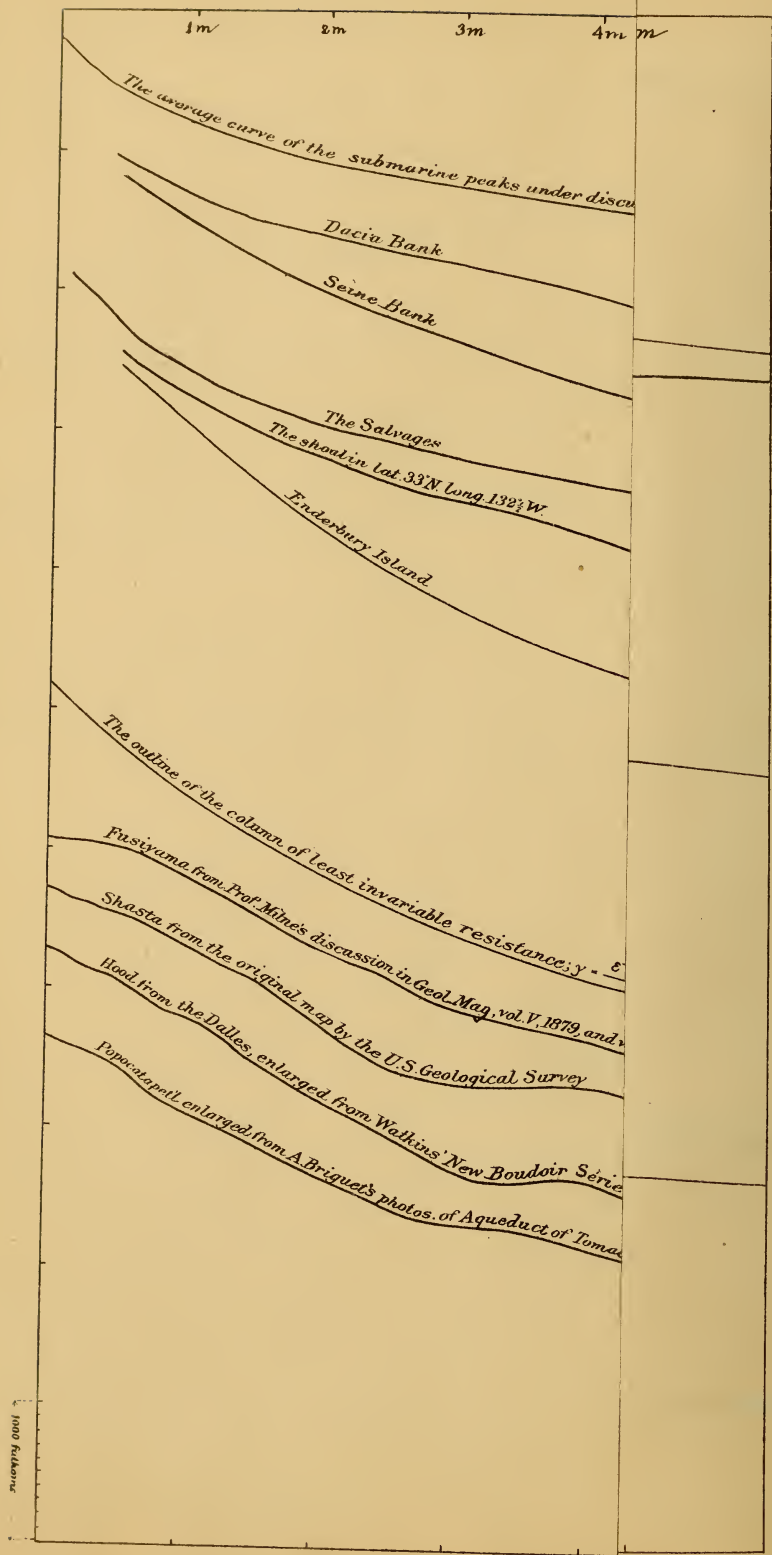
From which

$$B = +\ 641.8396$$
$$A = +\ 68.7985$$

Therefore the equation to the average of the outlines of the vertical sections of the submarine peaks under discussion is

$$x = +\ 68.7985 + 641.8396\ \varepsilon^{\log y},$$


1m
2m
3m
4m
5m
6m
7m
8m
9m
10m
11m
12m
13m
14m
15m
16m
The average curve of the submarine peaks under discussion, x = 687985 + 641 8396 ℓ^{1/2}
Decia Bank
Seine Bank
The Salvages
The shoal in lat 33° long 132° W
Enderbury Island
The outline of the column of least invariable resistance, y = ℓ^a ℓ^b
Pusiyama from Prof Milne's discussion in Geol. Mag. vol V. 1879, and vol VI. 1879.
Shasta from the original map by the U.S. Geological Survey
Head from the Dalles, enlarged from Watkins' New Boudoir Série
Papantzinl enlarged from A. Briquet's photos. of Aqueduct of Tomacoco M.H.
The comparison is to be made by vertical transposition


1m
2m
3m
4m
m
The average curve of the submarine peaks under discu
Dacia Bank
Seine Bank
The Salvages
The shoal in lat. 33°N. long. 132½°W.
Enderbury Island
The outline of the column of least invariable resistance; y = E
Fusiyama from Prof. Milne's discussion in Geol. Mag. vol. V, 1879, and
Shasta from the original map by the U.S. Geological Survey
Hood from the Dalles, enlarged from Watkins' New Boudoir Serie
Popocatepetl enlarged from A. Briquet's photos. of Aqueduct of Tomac
1000 fathoms

from which:

$$y = 0.33,\ 1,\ 2,\ 3,\ 4,\ 5,\ 6,\ 9,\ 10,\ 12,\ 14.$$
$$x = 465,\ 711,\ 936,\ 1103,\ 1241,\ 1360,\ 1466,\ 1733,\ 1813,\ 1937,\ 2088.$$

Both theory and actual examples show that there is a close agreement in general form and slopes between land and submarine peaks, and, while it is noticeable that those which are submerged are somewhat less steep than those on land, it is apparent that the latter have been formed with sufficient strength to resist the extra pressure to which they would be subjected if submerged.*

It is also shown that isolated formations occupying comparatively limited areas at the bottom can and do occur in deep water, and we are able to assign at once a maximum interval which should obtain between soundings taken to develop the general character of the bottom of the ocean or in searching for reported ocean shoals. Soundings taken 40 miles apart in a depth of 2,500 fathoms do not prove anything with certainty, except the depth at the points where they are taken, because it is possible with this interval to pass entirely over a formation rising from the bottom to within a short distance of the surface. The minimum radius at the bottom which a dangerous ocean shoal can have must vary directly with the depth, but on the average in the deep sea it may be stated as 10 miles. An interval of 10 miles coupled with an interval of 2 miles would be sufficient for general development, and would prove with certainty the existence or absence of any formation rising close to the surface. Of all the possible ways in which a 10-mile interval could lie with reference to a submerged peak, that which would be most advantageous for a prompt discovery is the condition in which one end of the interval is at the bottom of the slope and the other near the apex, and that which would be least advantageous is the condition in which the interval is bisected by the position of the apex. In the latter case there would be nearly equal soundings at both ends, but the soundings at the ends of the adjacent 2-mile intervals would immediately disclose the slopes. Whenever lines of deep-sea soundings are run, it is better and gives more useful information to place the soundings at alternate long and short distances apart. Thus it is better to take soundings along such a line at alternate intervals of 10 miles and 2 miles than at regular intervals of 6 miles. In most cases the 10-mile soundings will give as much information as the 6-mile soundings, but the 2-mile soundings at an average distance of 12 miles apart give definite information about the actual nature of the bottom, and not merely its average character.

* See Mr. G. F. Becker's paper on the form of volcanic cones, in the Am. Jour. of Science, 1885, p. 283.

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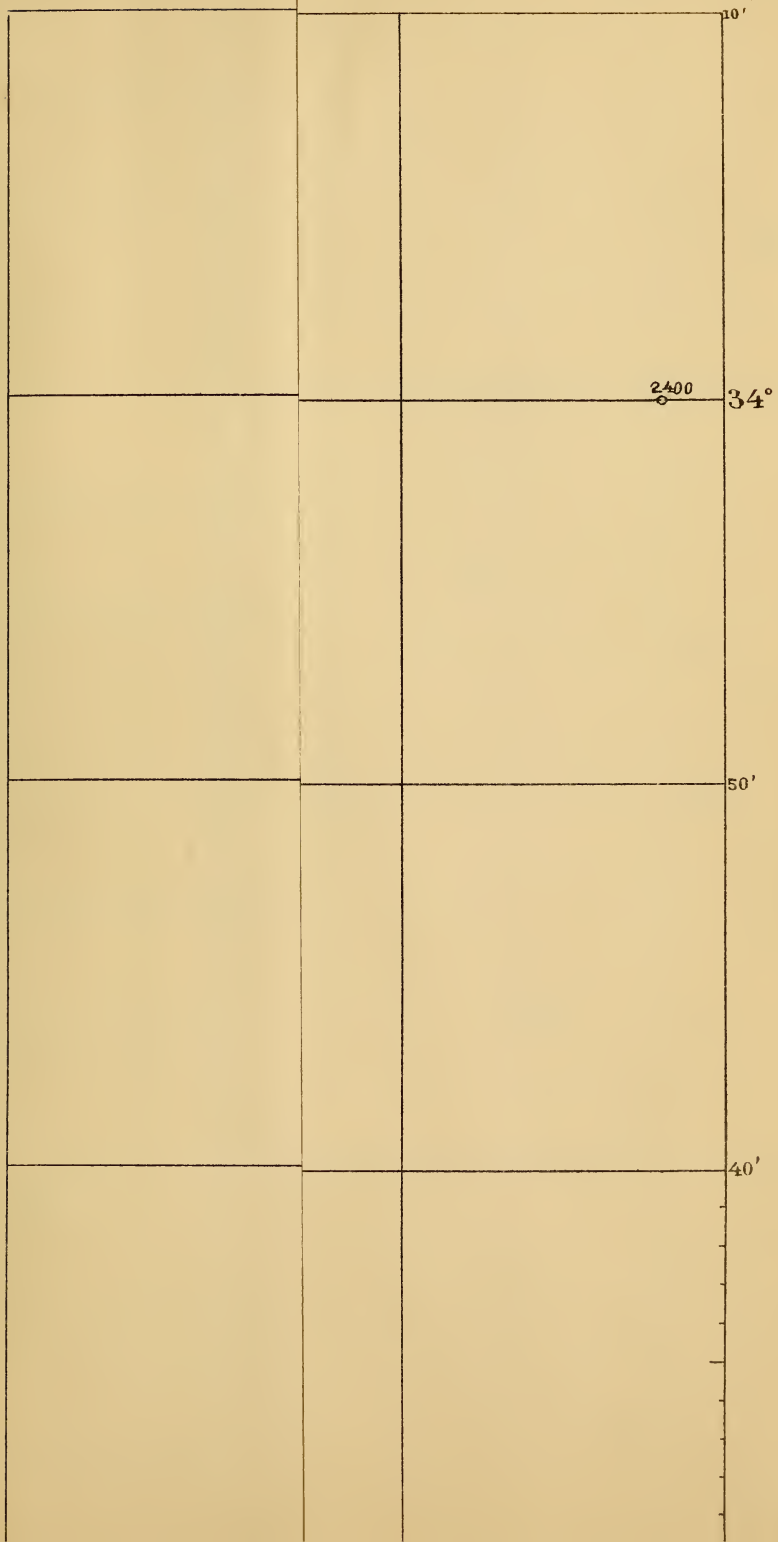
DACIA BANK


10'
2400
34°
50'
40'

SEINE BANK

10'
34°
50'
40'
30'
50'
40'
30'
20'
10'
14°00'
50
2250
2250
2400
2190
679
215
1149
207
93
807
289
111
92
589
1769
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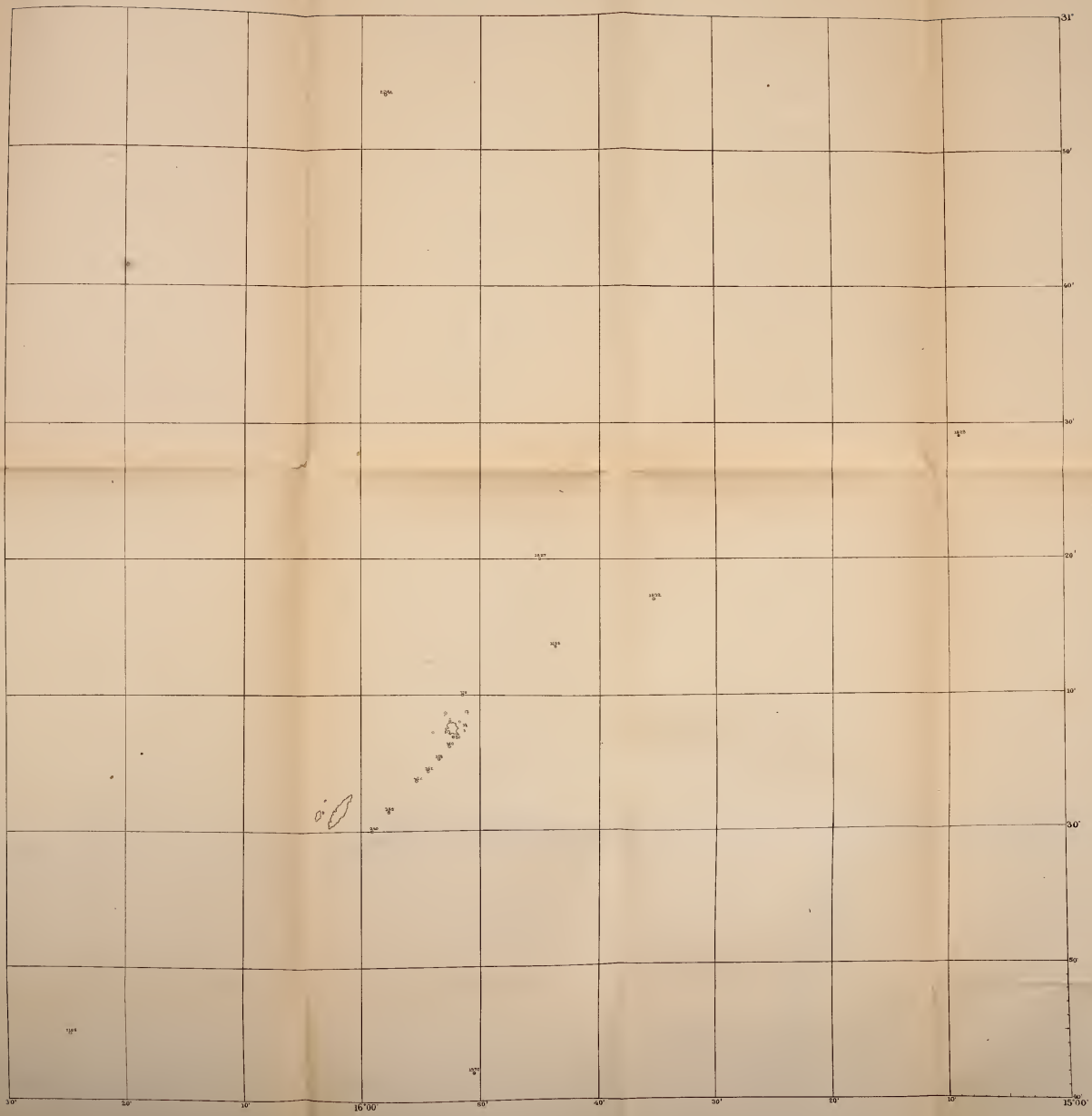
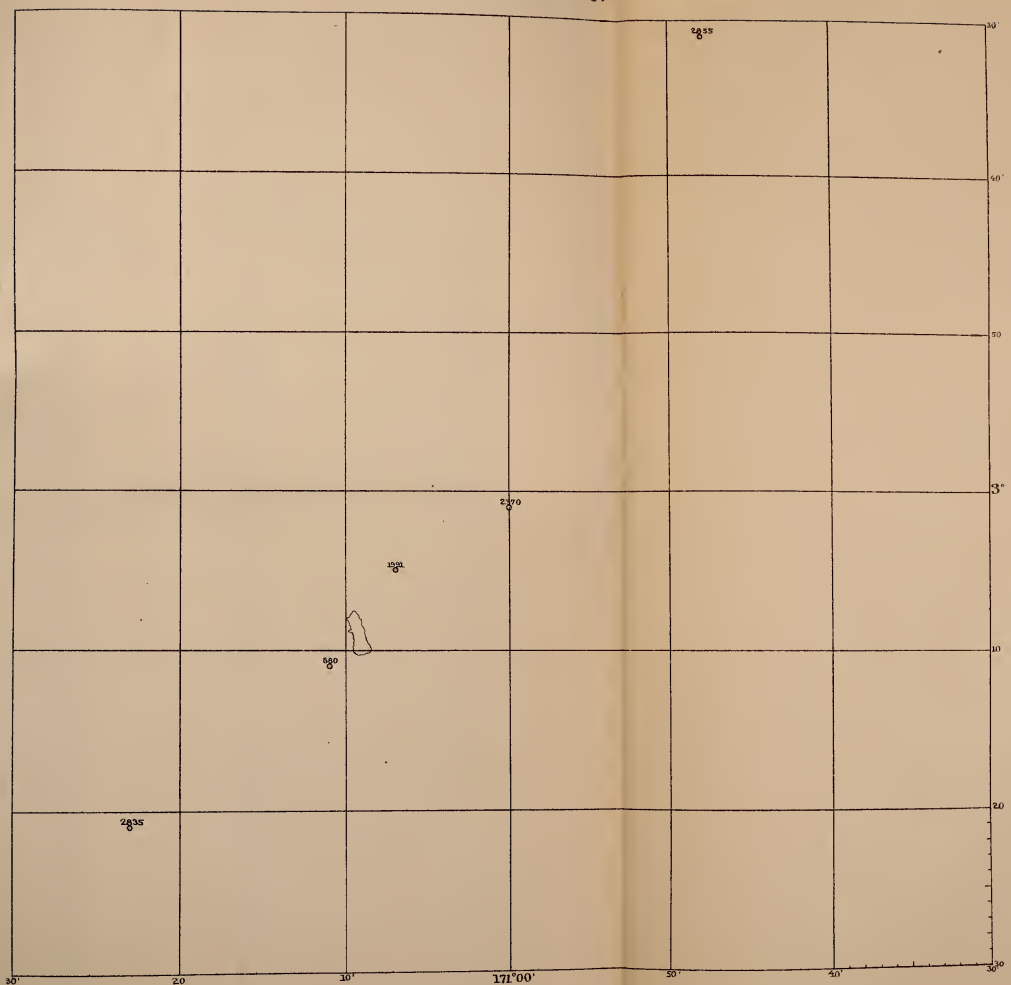
2325

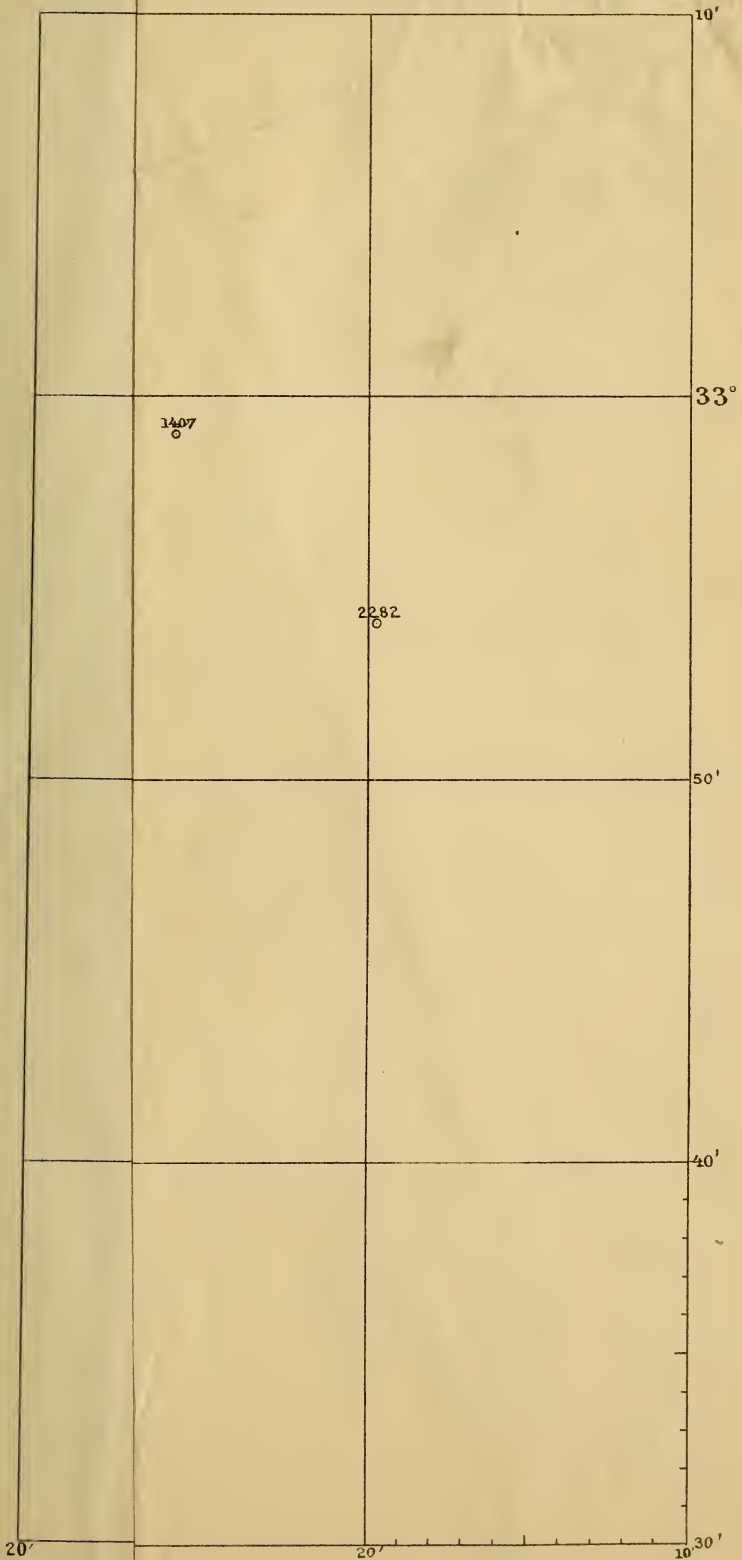
THE SALVAGE AND PITON IS.



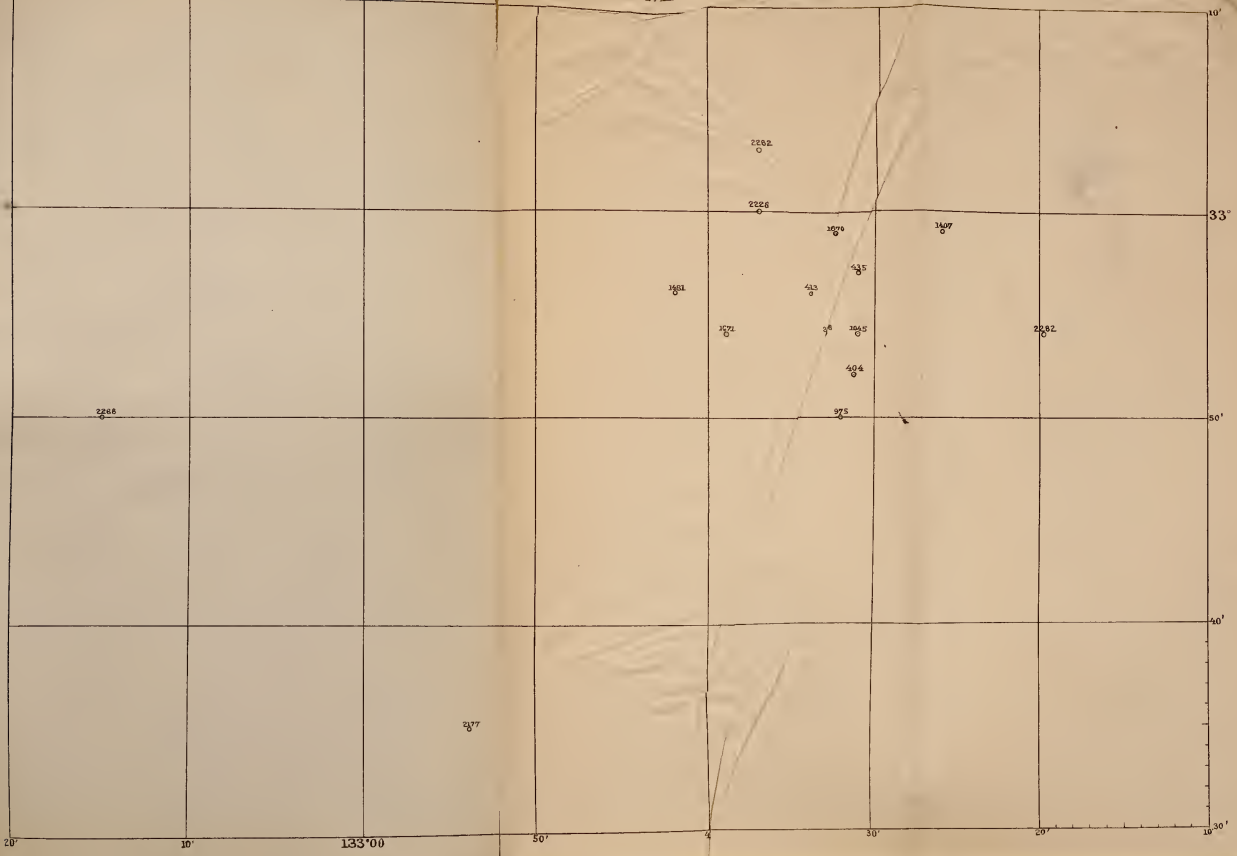
2
30'

ENDERBURY I.




10'
33°
1407
2282
50'
40'
30'
20'
20'
10'

SHOAL SPOT IN THE N.P. OCEAN



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